The Effects of Motivation on Perceived Stress:

A Study of Undergraduate Biomedical Engineering Students

at The University of Texas at Austin

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Abstract

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Title: The Effects of Motivation on Perceived Stress: a Study of Undergraduate Biomedical Engineering Students at The University of Texas at Austin

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There are not enough science, technology, engineering, and math (STEM) graduates to fill the U.S.'s STEM workforce. In fact, graduation rates for STEM degrees are decreasing. To counteract issues with student persistence in STEM, it is important to look at relationships among malleable predictors of persistence. Toward this goal, and given that stress is a predictor for persistence, I studied the relationship between motivation and stress in engineering students. In my study of 180 undergraduate biomedical engineering (BME) students at The University of Texas at Austin, I found that amotivation was positively correlated with perceived stress for male students and underclassmen. Breaking down amotivation into its constituent parts, competence, autonomy, and relatedness, results suggest that it is important to begin considering what changes can be made to develop skills to reduce feelings of incompetence, and improve students' sense of autonomy and community in the male and underclassmen BME populations.

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The Effects of Motivation on Perceived Stress: A Study of Undergraduate Biomedical Engineering Students at The University of Texas at Austin

The U.S. considers itself a world-leader in science, technology, engineering, and mathematics (STEM) (Lymn, 2016). In order to remain a leader in STEM innovation, however, it is important for universities and colleges to address the low graduation rates of students seeking STEM degrees. Experts at Georgetown University estimate that the number of STEM positions will increase by 0.3% between 2008 and 2018 (Carnevale, Smith, & Strohl, 2010). Unfortunately, the proportion of annual graduates with a Bachelor's degree in a STEM area is decreasing (President's Council of Advisors on Science and Technology (PCAST), 2012). The increase in STEM occupations and decrease in STEM graduates leaves an expected gap of one million people in the U.S. workforce (Carnevale et al., 2010).

Graduation rates in STEM depend in part upon enrollment and retention rates, which in turn vary by major and gender. Enrollment in STEM and engineering, in particular, is low: in 2012, the national STEM enrollment was 24.6% of all enrolled students, of which 5% were enrolled in engineering (19.2% female) (Falkenheim et al., 2017). Graduation with a STEM degree is also low: women earned 57.2% of all awarded Bachelor's degrees, 50% of all STEM degrees, but only 19.8% of engineering degrees in 2014 (Falkenheim et al., 2017). The low enrollment and graduation of students seeking STEM degrees, specifically women in engineering, has resulted in a gap in the STEM workforce. Understanding why enrollment and graduation in STEM is low will help reveal how those rates can be increased.

There are many factors affecting rates of matriculation and graduation of STEM students, such as how students are selected to participate in STEM programs (e.g., Ackerman, Kanfer, & Beier, 2013) and student experience in the program (e.g., Chen & Soldner, 2013; PCAST, 2012).

However, understanding students' motivation for STEM coursework is likely to be particularly informative in understanding student matriculation and retention in STEM majors. Namely, in line with years of motivation research across contexts (e.g., Ryan & Deci, 2000b), I posited that students who experience more autonomous forms of motivation (interest, personal value) as opposed to controlled forms of motivation (e.g., pressure, tension, guilt) or amotivation toward their STEM coursework may experience less perceived stress and in turn, may be more likely to persist in STEM majors.

As such, this study explored the relationship between motivation and stress among biomedical engineering students. In addition to examining that basic relationship, this study also allowed me to examine gender, year in degree, and post-graduation plans as potential moderators of the motivation-stress relationship. Exploring the role of these demographic factors is important to revealing a useful model for stress prediction. Motivation and stress both vary by gender, thus it is possible that gender may modify the relationship between motivation and stress. The prevalence of autonomous versus controlled motivation varies throughout a student's pursuit of his/her degree; the ability to cope with the stress that results may fluctuate as students adapt to their learning environment and develop coping mechanisms. It is also feasible that post-graduate plans (continued education in a graduate or professional degree versus entry into an industry role) may moderate the motivation-stress relationship, as individuals with the same controlled motivation may experience different levels of stress based on what it is that their motivation (or goals) encompass (e.g., medical school versus industry). Understanding the relationship between motivation and stress, and how gender, year in degree, and postgraduate plans interact with these variables, is important to revealing potential predictors of persistence in STEM, as stress is one critical predictor of persistence. Such knowledge of upstream predictors of persistence will help inform targeted interventions to increase persistence in STEM, and particularly engineering majors.

Student Persistence in STEM Majors

There are many factors affecting student persistence in STEM, varying from experiences before college, during college, and individual characteristics. The academic environment preceding college is critical to student success in STEM. From the TALENT data bank, comprising 50,000 males and 50,000 females per grade for grades 9-12, Wai et al. (2009) found that spatial visualization and mechanical reasoning predict postsecondary success in STEM fields (Ackerman, Kanfer, & Beier, 2013). However, the exposure and support students get in developing their spatial visualization abilities was found to vary depending on their schools, suggesting that high school experiences are critical predictors of later persistence in STEM college majors. Furthermore, assessments of spatial and mechanical knowledge favor male students, further exacerbating the gender imbalance in STEM (Wai et al., 2009). More generally, high school academic performance is also a predicting factor for persistence. Levin and Wycokoff (1991) studied the 1984 entering freshmen class of engineers at Penn State University, and found that high school GPA and performance on algebra and chemistry placement tests were positively correlated with persistence in studying engineering in college ($r = 0.751$, $r = 0.055$, $r = 0.053$, respectively).

A strong foundation of STEM-related knowledge (math, physics, science) is important for success upon entering a STEM major in college. In a study of 320 freshmen students from Emory University and Georgia Institute of Technology, Ackerman et al. (2001) found that both the number of advanced placement (AP) tests and scores received on those tests predicted STEM graduation. Most important for initial persistence in STEM were receiving credit for AP Calculus and completing more than three AP tests in a STEM subject.

Student experiences transitioning into college are also critical predictors for persistence in STEM through college. Choosing to enter into engineering for a genuine reason, such as for enjoyment of math, science, and problem solving, was a positive predictor, whereas pursuing engineering for a superficial reason, such as influence from parents or teachers, financial reward, job opportunities, or status alone was a negative predictor ($r = 0.223$, $r = -0.223$, respectively) (Levin & Wycokoff, 1991). Once in college, community identification can impact a student's likelihood to persist (Chen & Soldner, 2013). Students who fail to connect with the STEM community, through peers and professors, or who do not feel supported by the STEM community are less likely to persist (PCAST, 2012).

Individual characteristics, including demographic and psychosocial factors also play a role in predicting persistence in STEM. Being male is a positive predictor for persistence in engineering, whereas being female is a negative predictor of engineering persistence ($r = 0.314$, $r = -0.314$, respectively) (Levin & Wycokoff, 1991). The relationship between gender and persistence is a reflection of many variables, such as performance on AP tests (as discussed above) and feelings of self-worth.

In a meta-analysis, Robbins et al. (2004) found that across all majors, academic motivation and general self-concept were positively correlated with retention ($r = 0.105$ and $r = 0.059$, respectively). From their cohort of 35 first-semester chemistry students, Shedlosky-Shoemaker and Fautch (2015) found similar results for STEM students. Those students who switched from chemistry to a non-STEM major or who left college altogether related their identity and self-worth to competition and academic competence more so than students who persisted in their chemistry major (Shedlosky-Shoemaker & Fautch, 2015). Thus, as those students began to perform worse academically, their self-worth lowered. It may be that these switchers and leavers felt demoralized in competitive and academically challenging environments (Shedlosky-Shoemaker & Fautch, 2015).

Feeling the need to master a concept seems to be an important factor for persistence. In a cohort of 592 STEM freshmen at Georgia Institute of Technology, mastery/organization were strong predictors of STEM persistence; both the men and women who left STEM for non-STEM majors had low mastery/organization compared to those students who persisted in their STEM major (Ackerman, Kanfer, & Beier, 2013). Although similar in mastery/organization, male and female switchers did vary in anxiety: female switchers demonstrated significantly higher anxiety than male switchers (Ackerman, Kanfer, & Beier, 2013). A separate study by Webb et al. (2002) found that stress and pressure, similar constructs to anxiety, did predict persistence. Even students with a high academic competence for STEM were likely to switch out of a STEM major due to the academic pressure and stress associated with their studies (Hall & Sverdlik, 2016).

The literature suggests that these psychological constructs, stress, anxiety, and pressure, have an impact on predicting student persistence in STEM. Because stress is a factor that can be altered by behavior and environment (e.g., Keogh, Bond, & Flaxman, 2006), I explored predictors of stress, as stress is a direct link to student persistence in STEM. The prevalence of stress, and predictors of stress in STEM are discussed next.

Student Stress in STEM Majors

The collegiate learning environment is undeniably stressful. As students transition to postsecondary education, they are faced with many situations that threaten or pressure them, resulting in a physiological stress response. Stressful situations may be induced by academic factors: pressure to perform well on tests and papers; social factors: transition to a new living and academic environment and lack/loss of a social support network; and economic factors: concerns about paying for college and uncertainty about the future (Rizwan, Alvi, & Saeed, 2010). A 2015 survey of 16,760 undergraduate students at 40 different universities in the U.S. found that 43.1% of students reported more than average stress, with an additional 11.4% of students reporting tremendous stress. Female students (46.3% above average, 12.6% tremendous stress) reported higher stress than male students (36.8% above average, 8.7% tremendous stress) (American College Health Association, 2016).

Moreover, this trend in stress was not evenly distributed across all academic majors. Students pursuing a STEM degree tended to experience higher perceived stress than students in non-STEM majors. In a study of 265 third and fourth year undergraduates at a small private Midwestern university, May and Casazza (2012) found significantly higher perceived stress in “hard” science majors, defined as majors requiring more than six courses of math, chemistry, or biology, than “soft” science majors, majors requiring less than six courses of math, chemistry, or biology, ($p = 0.002$). A study by May and Kyle (2007) further found that undergraduate students in pharmacy and engineering experienced significantly more stress than those students in art and science majors, like English, History, Psychology, or Business.

Within STEM degrees, engineering students reported relatively higher levels of stress. A comparison of undergraduate medicine ($n = 100$), engineering ($n = 100$), and nursing ($n = 50$) students in India revealed that more medical and engineering students reported feeling stress (either normal levels or levels requiring clinical attention) than nursing students (Behere, Behere, & Yadav, 2011).

The increased psychological cost of pursuing a STEM major has implications beyond persistence; it impacts the academic and health outcomes of students.[1] Although I am focusing on stress as a predictor of persistence in STEM, the ancillary health benefits to reducing chronic stress in students should not be ignored.[2] Beyond reducing stress to increase persistence, it is important to reduce stress to improve public health.

Moreover, matriculation year and gender are critical demographic predictors of stress. Students who have progressed further in their degree tend to experience more stress than those who are just starting. In a study of 444 undergraduate students across engineering, medicine, and general course of study, Banerjee (2016) found that third semester students were significantly more stressed than first semester students. A study of 264 Pakistani medical students similarly

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[1] Chronic stress can cause anxiety and depression, and impede one's ability to adjust, experience pleasure, and emote. These effects ultimately lower one's life satisfaction and increase the likelihood of developing further mental issues later in life (Baum & Posluszny, 1999; Chemers, Hu, & Garcia, 2001; Krantz, Thorn, & Kiecolt-Glaser, 2013; Rathus, 2005; Weinstein, 2009).

[2] Under certain circumstances, stress can play a beneficial role in a student's educational experience. Dr. Daniela Kaufer of UC Berkeley found that acute stress improves brain performance, increasing alertness, performance, and memory (Jaret, 2015; Kirby et al., 2013; Sanders, 2013). In rats, acute stress causes brain stem cells to differentiate into nerve cells, which, once matured, improve the rats cognitive function (Kirby et al., 2013). In excess, however, these benefits of stress are minimized. Chronic stress has the opposite effect of acute stress; it elevates levels of the stress hormone glucocorticoid, which in turn suppresses neuronal production in the hippocampus and impairs memory (Sanders, 2013).

found that students in their final year felt more stressed (Shaikh et al., 2004). Stress also differs by gender. In her study of Indian undergraduate students, Banerjee (2016) found that female students experienced higher levels of stress than male students across all disciplines. May and Cassaza (2012) found that gender was a significant predictor of stress in their sample of 265 undergraduates.

Although a variety of environmental, personal, and academic factors may predict students' stress related to school (e.g., Everson, Tobias, Hartman, & Gourgey, 1993; May & Casazza, 2012; Rizwan, 2010), students' motivation is like to be a particularly promising predictor of the stress students experience in STEM coursework.

The focus on motivation is important because unlike the demographic factors that predict stress, motivation is malleable and readily influenced by support in the environment (e.g., Black & Deci, 2000a). The nature and role of motivation in STEM coursework, as well as the link between motivation and stress is discussed next.

Motivation for STEM Coursework

The nature of a student's motivation for pursuing a STEM degree is likely to be one critical predictor of his/her stress and persistence in the field. Motivation, or the desire to do something, can be discussed through various theories. For this study, I considered motivation through the lens of Self-Determination Theory (SDT). SDT is a commonly used theory to study motivation in STEM students, especially in engineering education research (e.g., Brown, McCord, Matusovich, & Kajfez, 2014). SDT classifies motivation based on the reason for acting, either intrinsic or extrinsic (Linnenbrink-Garcia & Patall, 2014). Intrinsic motivation refers to an individual's inherent interest in or enjoyment of a task, whereas extrinsic motivation refers to an individual's pursuit of a task because it results in a separate desirable outcome (Ryan & Deci, 2000a).

A person who acts exclusively out of intrinsic motivation cares only about the task at hand, and not about any outcomes that may result from the task; he/she finds enjoyment and satisfaction from the performance of the task itself. Intrinsic motivation embodies the innate curiosity of creatures (Ryan & Deci, 2000a). According to Vallerand et al. (1993), intrinsic motivation can be further categorized into motivation to know, to accomplish, and to experience stimulation, as shown in Figure 1. Intrinsic motivation to know represents performing an action for the joy and satisfaction experienced while learning. Intrinsic motivation to accomplish represents similar feelings of joy and satisfaction in the act of executing a task. Intrinsic motivation to experience stimulation defines performing actions for the stimulating sensations experienced in the process (Vallerand et al., 1993). All forms of intrinsic motivation are defined by their internal perceived locus (Ryan & Deci, 2000a). That is, intrinsically motivated actions are experienced as originating within the person and driven by the individual's authentic interests.

Unlike intrinsic motivation, extrinsic motivation ranges from somewhat autonomous to non-autonomous. Integrated extrinsic motivation is most like intrinsic motivation; both have an internal perceived locus of causality. Integrated actions represent an individual's personal values and self-identity (Linnenbrink-Garcia & Patall, 2014). Integrated actions are fully consistent with how the individual conceptualizes the self, even if not wholly enjoyable or interesting. Identified extrinsic motivation begins to shift away from a fully internal locus of causality. It is the motivation to act based on the belief that the behavior is useful or important for achieving a separate personal goal, even though the action may not be enjoyable (Linnenbrink-Garcia &

Patall, 2014). Introjected extrinsic motivation, also with a partially internal locus, stems from an individual pressuring him/herself to perform the action. Introjected actions result in personal "feelings of obligation, guilt, or pride" that are themselves experienced as controlling, though the control is internal (Linnenbrink-Garcia & Patall, 2014). Externally regulated extrinsic motivation, with a fully external locus, is the motivation to do something because of external consequences (e.g., money, rewards) or pressure from another person (Ryan & Deci, 2000b; Vallerand et al., 1993).

The level and orientation (as shown in Figure 1) of student motivation plays a critical role in educational outcomes. Academic motivation is well known to predict student functioning, including outcomes such as academic performance, persistence, and well-being (Burton, Lydon, D'Alessandro, & Koestner, 2006; Ryan & Deci, 2000; Vallerand & Bissonnette, 1992). Prior research has suggested that students who demonstrate more autonomous forms of motivation will have more desirable academic and/or well-being outcomes compared to students who demonstrate more external forms of motivation (e.g. Burton et al., 2006; Ryan & Deci, 2000). Among a group of 1062 French-Canadian students from a junior college in the Montreal area, Vallerand and Bissonnette (1992) found that internal forms of motivation (intrinsic motivation and integrated and identified extrinsic motivation) were positively related to behavioral persistence in a junior college course, whereas more external forms of motivation (external and introjected extrinsic motivation) were not related to behavioral persistence in the course. Amotivation, as expected, was negatively correlated to behavioral persistence (Vallerand & Bissonnette, 1992). In a study of 241 elementary school children in Toronto, Burton, Lydon, D'Alessandro, & Koestner (2006) found that intrinsic motivation predicted elementary school students' psychological well-being, independent of student's academic performance, while identified motivation predicted a positive association between student's well-being and academic performance. The more identified regulation the student exhibited, the better his/her academic performance, and the more his/her well-being depended upon academic performance. The researchers did not explore controlled nor extrinsic motivation as a predictor of psychological well-being or academic performance (Burton et al., 2006).

Moreover, for STEM specifically, motivation predicts persistence. One study of the 1984 entering freshman class in the College of Engineering at Penn State University looked at student admission records, counseling activity, transcripts, registrar records, and personal interviews to explore persistence and success in undergraduate engineering (Levin & Wycokoff, 1991). The results of this study suggested that students who were motivated to choose STEM based on a genuine, intrinsic interest in the field were more likely to persist in their engineering degree, even if their academic performance was lower (Levin & Wycokoff, 1991). Alternately, students who chose STEM based on extrinsic reasons, such as the status and financial benefits of a job in STEM, were more likely to leave their engineering major, even if they did succeed academically (Levin & Wycokoff, 1991). Burtner (2005) conducted a longitudinal study of 138 freshmen engineering students to further explore persistence in an engineering major. She similarly found that students were more likely to switch out of engineering if they chose engineering based on the expectation of a secure, high-paying job after graduation and lacked confidence in their academic ability. Selecting a course of study, especially in STEM, for intrinsic reasons is a positive predictor of persistence in that STEM major.

In addition to persistence, motivation can predict stress in STEM students. A study of 146 college psychology students from the Netherlands found that neither intrinsic nor extrinsic motivation predicted stress ($p = 0.28$ and $p = 0.70$, respectively), but amotivation did predict stress ($p < 0.1$) (Rucker, 2012). In a group of 137 students enrolled in an organic chemistry course at a small eastern U.S. college, those students who enrolled in the course of their own volition (entered with autonomous motivation) demonstrated lower anxiety, along with greater competence, interest/enjoyment, persistence in the course, and less grade-focused goals than those students who had lower autonomous motivation (Black & Deci, 2000).

Finally, it is important to note that the level and orientation of motivation is also influenced by gender. A study by Vallerand and Bissonnette (1992) of 1,042 first-term French college students found that female students were more intrinsically motivated and integrated/identified extrinsically motivated than male students. The female students were also less extrinsically or amotivated than the male students. Furthermore, those female students had a lower drop-out rate than the male students (9.5% vs. 16.2% for male students) (Vallerand & Bissonnette, 1992). As such, links between motivation and other variables may vary by gender.

Clearly, motivation plays an important role in a number of educational outcomes, including those particularly relevant to STEM students, namely persistence. However, the extent to which academic motivation predicts stress among engineering university students has not been well studied. Given the high levels of stress among STEM students and the variability between STEM disciplines, understanding the extent to which motivation contributes to the stress levels of engineering students is of great importance.

Research Question

With this study, I explored the relationship between motivation, as viewed through self-determination theory and measured by relative autonomy index (RAI), autonomous, controlled, and amotivation, and perceived stress in undergraduate biomedical engineering students. How is motivation style related to perceived stress in undergraduate biomedical engineering students? I expected to find that perceived stress is negatively correlated with relative autonomy index and autonomous motivation, and positively correlated with controlled motivation and amotivation.

I also analyzed the motivation-stress association moderated by gender, year in degree, and post-graduation plans. I expected that female students would have a stronger negative correlation between motivation and stress. I expected that upperclassmen would have a weaker correlation between motivation and stress than underclassmen, as they adapt to their environment and develop mechanisms to cope with stress. For post-graduation plans, I expected that students intending to pursue further education would have a weaker correlation between motivation and stress than students intending to go into industry, as it is more difficult to find a satisfying industry job in BME than a graduate research position in BME.

By discovering the relationship between motivation style and perceived stress, I can tailor intervention plans to specific clusters of students not only to improve stress-related health outcomes for students, but also to promote their pursuit of knowledge and successful graduation with a STEM degree.

Methods

Setting

This study was conducted amongst undergraduate biomedical engineering students at The University of Texas at Austin. The University of Texas at Austin (UT Austin) is a large public institution that hosts a strong engineering school. Biomedical Engineering is a unique part of the engineering school in that it relies upon a broader base of fundamental science courses than other traditional engineering degrees. Due to the strong foundation in basic science courses, biomedical engineering students tend to pursue different career paths than other engineers. A portion of students in the department apply to medical school and other health professions programs. Another group of students seek out further education in engineering graduate school. These two career paths are not as common in other engineering degrees, where the majority of students enter immediately into industry positions.

Biomedical Engineering also varies in its student demographics. Women are historically a minority in engineering, with relative percentages of less than 30%. In Biomedical Engineering, however, the ratio of male to female students is nearly equal. For the 2015-2016 academic school year, undergraduate enrollment in Biomedical Engineering at UT Austin was 46% women.

Although an engineering discipline, Biomedical Engineering is unique from other engineering majors, and merits unique investigation.

Participants

All undergraduate students (N = 500) in the Department of Biomedical Engineering at UT Austin were eligible to participate in the study. A total of 193 undergraduate students participated in the study by returning the completed study survey (38.6% response rate). Thirteen surveys were discarded due to missing data, resulting in 180 usable responses. The participants were 60% female, with a mean age of 20.2 years (SD = 1.2). See Table 2 for a further characterization of the descriptive statistics for the participants.

Materials

The survey (see Appendix A) included several demographic questions about students' age, gender, and ethnicity. It asked about work, degree pursuit, involvement in the biomedical engineering community, and likelihood to persist in biomedical engineering. Finally, the survey included measures to assess students' academic motivation in engineering, perceptions of the learning climate in the engineering courses, and experiences of stress in engineering courses. These measures are described next.

Academic Motivation. Academic Motivation was assessed using 21 items adapted from the Academic Motivation Scale (AMS) (Vallerand et al., 1992). The AMS evaluates an individual's intrinsic, extrinsic, and amotivation toward education. In the original questionnaire, four statements are included to gauge the motivation level of seven types of motivation: intrinsic motivation to know, to accomplish, and to experience motivation; external, introjected, and identified regulation extrinsic motivation; and amotivation. In response to the question "Why are you studying Biomedical Engineering?", adapted from "Why do you go to college?", a typical statement is "For the pleasure that I experience in broadening my knowledge about subjects that appeal to me." Each question was scored for agreement on a 7-point Likert scale ranging from 1 (Strongly Disagree) to 7 (Strongly Agree). I then averaged the score for each motivation type, with higher scores corresponding to a stronger association with that motivation style. Vallerand et al. (1992) found sufficient reliability and stability for their questionnaire (mean Cronbach's alpha = 0.81). For this study, I selected the three statements within each motivation type that had the highest confirmatory factor analysis score, resulting in 21 total questions to gauge student's academic motivation. For the modified 21-question AMS used in this study, the mean Cronbach's alpha is 0.78 (SD = 0.10), which is comparable to the alpha measured by Vallerand et al. (1992) in the full 28-question AMS (alpha = 0.81, SD = 0.09). The reliability of the seven motivation measures are shown in Table 1.

I compiled the motivation profiles of each student into representative motivation scores. For a conglomerate score of motivational autonomy, I calculated the relative autonomy index (RAI) by weighting the different motivational scores based on their representation of autonomy:

-2*(externally regulated extrinsic motivation) – (introjected extrinsic motivation + identified extrinsic motivation) + 2*(intrinsic motivation to accomplish + intrinsic motivation to know + intrinsic motivation to experience stimulation). This iteration of the RAI is used to predict variables of interest (e.g., Vallerand & Bisonette, 1992). I also calculated separate scores for autonomous motivation (the average of identified regulation, intrinsic motivation to know, intrinsic motivation to accomplish, and intrinsic motivation to experience stimulation) and controlled motivation (the average of external regulation and introjected regulation).

Perceived Stress. Perceived stress was measured using the ten-item Perceived Stress Scale (PSS), modified to reflect stress perceptions for the Fall 2016 academic semester (Cohen, Kamarck, & Mermelstein, 1983). The PSS uses ten statements to gauge how stressful an individual feels his/her life is. Participants are asked to answer, for example, "During the Fall 2016 semester, how often had you been upset because of something that happened unexpectedly." Questions were scored on a five-point Likert scale ranging from 0 (Never) to 4 (Very Often), and then averaged, with the four positive questions inverted. The final score ranges from 0 to 4, with 4 representing the greatest value of perceived stress. Cohen, Kamarck, and Mermelstein (1983) found their scale to be reliable, with a mean Cronbach's alpha = 0.85. In this study, the Cronbach's alpha is 0.84.

Procedure

A single survey measuring students' motivation, stress, and various demographic characteristics was distributed to all eligible undergraduate students (N = 500) in the Department of Biomedical Engineering at The University of Texas at Austin (UT Austin). I distributed the online survey from February 1, the 12th class day of the Spring 2017 semester, through February 15, 2017. The survey, hosted on Qualtrics, was distributed via biomedical engineering courses, either in class or via Canvas, the online course management system; e-mail listservs associated with all BME student organization; e-mail to the undergraduate listserv from the department academic advisor; and Facebook posts in student organization and cohort groups. I also messaged students individually, personally asked them to participate, and encouraged interested participants to ask their friends to complete the survey. Students had up to two weeks to complete the survey, which itself took at most ten minutes to complete.

Statistical Analysis

For my data analysis, I used R version 3.2.2. To characterize the sample population across the variables of interest, I used non-parametric tests to account for the lack of normality. However, to answer my main research questions, I focused my analysis on creating linear regressions with multiple variables and interactions between those variables. To narrow in on the motivational variables of interest, I made a Spearman's correlation matrix. Based on the significant correlations from that matrix, I made linear regression models using the unmodified variables, then using centered variables. I then probed the centered models which had significant slopes for the variables of interest. For all tests of statistical significance, I used $\alpha = 0.05$.

Results

In my analysis, I first characterized the participant pool in terms of relevant demographic factors and variables of interest. To understand further the participant characteristics, I looked at students' perceived stress, motivation across the potential moderating variables of gender, academic classification, and post-graduation classification. After understanding how these variables differed in my population, I created models to explore the relationship between motivation and stress, incorporating the potential moderating variables and associated interactions.

Participant Demographic Descriptive Statistics

The survey participants represented a fairly equal distribution of academic classification (e.g., first year in BME, second year in BME). As shown in Table 2, 21% of the students were in their first year in BME (BME start semester = Spring 2017 or Fall 2016), 22% in their second (Fall 2015), 26% in their third (Spring 2015 or Fall 2014), 29% in their fourth (Fall 2013), and 2% in their fifth (Fall 2012). This distribution, however, was disproportionate to the actual academic classification distribution in BME at UT Austin, where class size decreases as the cohort ages (due to student attrition). The ethnic distribution of survey participants was mainly European American or White (41%) and Asian, Pacific Islander, or Asian American (37.36%), which is similar to the actual population, although no data regarding ethnic composition of the UT Austin BME Department is publically available. The gender distribution was skewed towards female participants (60%), where the BME Department only had 47% female students enrolled in the 2015-2016 school year.

Student Stress and Motivation Descriptive Statistics

To better understand my sample, I explored the perceived stress and motivation by potential moderating variables: gender, academic classification, and post-graduation plans.

First, I looked at the distribution of my main variables of interest. The mean stress for the sample was 2.10 (SD = 0.60) on a range from 0 – 4. This distribution was not normal (Shapiro-Wilk $p = 0.04$). The sample mean RAI was 21.27 (SD = 5.88) on a scale from -21 – 42, and was also non-normally distributed (Shapiro-Wilk $p = 0.03$). The sample autonomous motivation was 5.23 (SD = 0.82), the controlled motivation was 5.06 (SD = 0.99), and the amotivation was 1.34 (SD = 0.53). Since none of the variables were normal, I performed non-parametric tests for significance (either Kruskal-Wallis test with a post-hoc Dunn test for multiple pair-wise comparisons, or a Wilcoxon rank-sum test for a single comparison).

I then looked at stress, RAI, autonomous, controlled, and amotivation across gender. As shown in Table 3, the mean perceived stress among the 71 male participants was 1.99 (SD = 0.66), among the 109 female participants was 2.17 (SD = 0.55. There was a statistically significant difference in the perceived stress between the two genders ($p = 0.04$). None of the motivation scores, however, varied by gender. For men, their mean RAI was 20.6 (SD = 6.27), for the women, 21.74 (SD = 5.64). For the other motivation scores by gender, see Table 3.

I also looked at stress and motivation between students at different stages in their BME education. A comparison by the semester students started BME revealed that there was only a difference in controlled motivation by semester. However, no difference was significant for alpha = 0.05. Table 4 details the mean and standard deviation for stress and motivation scores for cohorts of students based on their start semester. I also created a new variable, academic classification (AC), to group participants based on their status as underclassman (Spring 2017, Fall 2016, Fall 2015, and Spring 2015) or upperclassman (Fall 2014, Fall 2013, Fall 2012). Across academic classification, there was a significant difference for autonomous and controlled motivation. Underclassmen had a higher autonomous motivation than upperclassmen (M = 5.39, SD = 0.82; M = 5.10, SD = 0.82, respectively; $p = 0.01$). Underclassmen also had a higher controlled motivation than upperclassmen (M = 5.29, SD = 1.00; M = 4.88, SD = 0.89, respectively; $p < 0.01$).

My analysis of stress and motivation by post-graduation plans did reveal between-group differences, as shown in Table 5. Post-graduation plans were recorded as grad school, STEM; grad school, non-STEM; medical school; industry; and other. There was no significant difference in stress between the five post-graduation groups ($p = 0.75$), however, there was a difference in RAI, autonomous motivation, and amotivation between the groups ($p < 0.01$, $p = 0.02$, $p < 0.01$, respectively). Students intending to go to graduate school in a STEM subject had a higher RAI than students intending to go into an industry position (mean = 23.67, SD = 5.51; mean = 20.02, SD = 5.50; $p < 0.01$), as shown in Figure 2. Figure 3 shows that students intending to go into a STEM-related graduate program had higher autonomous motivation that students intending to go into a non-STEM-related graduate program (M = 4.83, SD = 1.02; M = 4.50, SD = 0.86; $p = 0.03$). Figure 4 shows that students going into STEM-related graduate school had lower amotivation scores than students going into non-STEM-related graduate school or industry (STEM: M = 2.04, SD = 1.21; non-STEM: M = 4.00, SD = 2.00; Industry: M = 2.77, SD = 1.30; $p = 0.02$, $p = 0.01$, respectively). I then made a post-graduation classification (PGC) variable to group participants by post-graduation plans for further education (grad school, STEM; grad school, non-stem; medical school) and for corporate/industry positions (industry, other). There was still no difference in stress between the two groups ($p = 0.52$), but there was a difference in RAI, controlled motivation, and amotivation. Student's intending to seek further education had greater RAIs than students intending to enter the corporate world (mean = 22.02, SD = 6.05; mean = 20.20, SD = 5.49; $p = 0.02$). Students entering into the corporate world had more controlled motivation than those pursuing further education (M = 5.24, SD = 0.85; M = 4.93, SD = 1.01; $p = 0.05$). A similar trend was true for amotivation scores between students pursuing corporate versus further education (M = 2.76, SD = 1.29; M = 2.36, SD = 1.35; $p = 0.01$).

The Extent to which Motivations Predicts Stress

To explore further whether motivation predicted perceived stress in my sample, I computed correlation coefficients among the continuous variables (stress, RAI, autonomous

(AUT), controlled (CONT), and amotivation (AMOT), and semester students started BME), then iteratively made linear regression models.

Using Spearman's correlation coefficients for non-normal variables, I found no correlation between perceived stress and RAI, AUT, or CONT ($p = 0.36$, $p = 0.31$, $p = 0.97$, respectively). I did, however, find a significant, if weak, correlation between amotivation and perceived stress (coefficient = 0.20, $p = 0.01$). All coefficients and p-values are shown in Table 6. Because the correlation between amotivation and perceived stress was the strongest, I chose to develop linear regression models for those two variables.

To confirm that there was a relationship between AMOT and stress, I began creating different regression models, as shown in Table 7. I began with a simple linear regression where AMOT was the independent variable predicting perceived stress (Model 1). AMOT was a statistically significant predictor of stress in the model ($p < 0.01$). To explore whether gender, academic classification, or post-graduation plans were potentially moderating the relationship between AMOT and stress, I created new models that included the potential moderating variable and the interaction between that variable and AMOT. I first added gender as a potential moderator (Model 2). AMOT, gender, and the interaction were significant to the model ($p < 0.01$, $p = 0.01$, $p = 0.05$, respectively). However, when I replaced gender and its interaction with academic classification (underclassman vs. upperclassman) and interaction (Model 3), AMOT remained statistically significant, while academic classification was not ($p < 0.01$, $p = 0.13$, $p = 0.10$, respectively). The last potential moderator I evaluated was post-graduation classification (corporate vs. further education) (Model 4). As with the Model 3, AMOT was significant, but the potential moderator was not a statistically significant predictor of stress ($p < 0.01$, $p = 0.53$, $p = 0.39$). Model 5, which included all potential moderators and interactions, resulted in statistical significance for AMOT, gender and its interaction, and academic classification and its interaction, but not post-graduation classification nor its interaction ($p < 0.01$, $p < 0.01$, $p = 0.02$, $p = 0.04$, $p =0.03$, $p = 0.59$, $p =0.51$, respectively). Model 5 also accounted for the most variability in stress across amotivation ($R^2 = 0.11$).

To ease the interpretation of the results of these models, I calculated and used the centered variables, where the grand mean for a variable is subtracted from each data point of that variable. I recreated Models 1 – 5 with centered variables, shown in Table 8.

The simple linear regression between amotivation and perceived stress (Model 6) was significant in terms of the slope ($p < 0.01$). When I added gender and its interaction (Model 7), all three independent variables, AMOT, gender, and the G-AMOT interaction were significant ($p < 0.01$, $p = 0.05$, $p =0.04$, respectively). In Model 8, I replaced gender with academic classification. Although amotivation was still significant ($p < 0.01$), neither academic classification nor the AC-AMOT interaction were significant ($p = 0.93$, $p = 0.10$, respectively). Similarly for Model 9, where the second independent variable is post-graduation classification (PGC), AMOT was significant ($p <0.01$), but both PGC and the PGC-AMOT interaction were not ($p = 0.79$, $p = 0.39$, respectively). However, when all potential moderating variables and their interactions were included (Model 10), AMOT, gender, AMOT x Gender, and AMOT x AC were all significant ($p < 0.01$, $p = 0.04$, $p = 0.02$, $p = 0.03$, respectively). Academic classification, and post-graduation classification and its interaction were still not significant ($p = 0.76$, $p = 0.52$, $p = 0.49$, respectively).

I then probed the gender-motivation and academic classification-motivation interactions in Model 10, using the un-centered gender variable and un-centered academic classification variable, respectively. As shown in Table 9 and Figure 5, there was a different trend between amotivation and stress for male and female students. For men, amotivation was a positive predictor of stress (slope = 0.21, $p < 0.01$). For women, although the trend between amotivation and stress was also positive, it was much weaker and not significant (slope = 0.07, $p = 0.22$). Table 10 and Figure 6 show the relationship between amotivation and stress for under- and upperclassmen. For underclassmen, amotivation was a significant positive predictor of stress (slope = 0.20, $p < 0.01$). For upperclassmen, however, amotivation was not a significant predictor of stress (slope = 0.05, $p = 0.22$).

Discussion

The main goal of this study was to explore whether there was a relationship between student motivation and perceived stress, and whether that relationship was moderated by gender, academic classification (underclassman vs. upperclassman), and/or post-graduation classification (corporate vs. further education). Before delving into my main research question, I wanted to compare my variable descriptive statistics against trends found in the literature.

Stress Descriptive Statistics

In my sample, stress only varied by gender. Perceived stress was greater in female students than in male students, which supports the literature on student stress in college, and in STEM, particularly, where females experience greater stress across all disciplines (American College Health Association, 2016; Banerjee, 2016; May & Casazza, 2012). However, there was no difference in stress by academic classification, which contradicts the literature showing that upperclassmen experience greater stress than underclassmen (e.g., Banerjee, 2016; Shaikh et al., 2004). The lack in variation of student’s perceived stress by subpopulations other than gender may indicate that the participant population is too homogenous. The foundational student experience in BME is relatively consistent; for the most part, students take the same courses from the same professors in the same temporal arrangement. This inter-student similarity may result in the similar perceived stress scores.

Amotivation Predicts Stress

Of the four motivation scores analyzed, amotivation was the only motivation score that predicted stress. There was not a significant correlation between relative autonomy index, a conglomerate score of student motivation, autonomous motivation, or controlled motivation and perceived stress. Amotivation, however, did predict student's perceived stress.

The conclusion that amotivation predicts stress, whereas autonomous and controlled motivation do not is consistent with the literature (Rucker, 2012). However, the conclusion that RAI did not predict stress varied from the results found by Black & Deci (2000) in their study of organic chemistry students. They found that college students who enrolled in an organic chemistry course of their own free-will, thereby demonstrating autonomous motivation to enroll in the course, experienced less anxiety. In my study, an increase in RAI, which is a related measure of autonomous motivation, did not predict stress.

Stress and anxiety, though different, are linked. Stress is the psychological and physiological response to some sort of stressor. When stress becomes chronic, it can result in anxiety. Thus, stress and anxiety are related, and may have the same or similar predicting variables. Since anxiety is a result of extreme levels of stress, it is possible that the levels of stress experienced by BME students at UT Austin are not great enough to induce anxiety. Since the PSS did not specifically measure acute vs. chronic stress, it is difficult to confidently extrapolate the PSS score to any side effects, like anxiety.

Gender and Academic Classification Moderate the Amotivation-Stress Relationship

Amotivation is a weak positive predictor of student's perceived stress. Furthermore, this relationship is moderated by gender and academic classification. Males experience an increased positive relationship between amotivation and stress, whereas females did not experience a significant correlation between amotivation and perceived stress. Underclassmen also exhibited a significantly positive correlation between amotivation and perceived stress, whereas the positive trend for upperclassmen was not significant.

That the trend between amotivation and stress holds for males but not females can be explained via Self-Determination Theory and the K-12 academic environment. Amotivation, as defined by SDT, characterizes inaction or action without intent. People who are amotivated do not value an activity, feel incompetent while performing the activity, and/or do not expect the activity to yield a desired outcome (Ryan & Deci, 2000b). I will first focus on the importance of feelings of incompetence in males vs. females.

In the K-12 setting, males are supported in math and science subjects; they are told that they are good at math and science. Females, on the other hand, are expected to excel in the arts, rather than STEM subjects. Thus, girls who are interested in STEM must fight a societal norm that tells them they won't be good scientists or engineers. Due to this academic bias females face in their K-12 education, they may be more used to feelings of incompetence. Females learn how to fight this adversity in order to achieve; they overcome those feelings of incompetence and develop the skills necessary to convert their believed incompetence into competence. Males do not have the same opportunity to develop skills of overcoming hardship in academics, since they do not face the same societal bias to their pursuit of STEM.

Due to gender-based experiences in K-12, female students may be more equipped to deal with the difficult college courses and the associated feelings of incompetence than male students.

When both male and female students transition from high school to college, females are experienced in handling feelings of incompetence and overcoming those feelings. Males, on the other hand, are not used to feeling academically incompetent, and instead begin to develop sentiments of amotivation toward their degree.

According to SDT, people choose to engage in activities based on a desire for competence, autonomy, and relatedness (Brown et al., 2014). Feelings of incompetence, if not successfully handled, will result in amotivation toward a particular activity. Thus, male students who are unable to overcome their feelings of academic incompetence, are likely to express increased levels of amotivation. Furthermore, people who are amotivated may experience low personal control beliefs and social withdrawal (Baker, 2003). For males, connection to peers is important to academic success and mental health (Hefner & Eisenberg, 2009; Shapiro, 2011). Social withdrawal would therefore exacerbate issues of academic success and mental health, which could express itself as stress.

A desire for competence is not the only predictor for engagement. I will look at autonomy and relatedness, the other two factors for engagement, to explain the positive trend between amotivation and stress for underclassmen, rather than upperclassmen. Autonomy is a metric of control. For underclassmen, transitioning environments from high school and home to college may result in a loss of autonomy. The college environment is foreign, and filled with new people, places, and professors. Freshmen and sophomores may feel that they have less control over their life since everything is so new. As they mature, they adjust to their environment, and begin to feel in control again. A similar explanation holds for relatedness, which represents how well one fits in with others. As students progress through their BME degree, their cohort grows closer together. The communal struggles shared by the students through their coursework unites them. Those peer-peer bonds formed are important to success (Hefner & Eisenberg, 2009). Without those bonds, and without feelings of control and competence, negative outcomes, such as stress, will increase.

For upperclassmen, issues of amotivation are not important for predicting stress. It seems natural that given time, students will begin to feel in control of the social and academic experiences, and feel a part of the BME community. Feelings of incompetence, however, may still remain, as courses only increase in difficulty throughout the BME degree. Since students do regain control and connection over time, the issue of incompetence is easier to manage, and is no longer significant for predicting stress.

To further explore the interactions between motivation, stress, and the surrounding academic environment, I plan to look at the role learning climate has in a motivation-stress model. In my preliminary analysis, I found that learning climate was significantly correlated to stress, RAI, extrinsic motivation, intrinsic motivation, and the semester students started their BME coursework. Since learning climate is a malleable characteristic predicting stress, it is important to understand how it interacts with other variables predicting stress to further motivate what changes should be made in the engineering education environment to reduce stress and increase persistence.

Limitations and Strengths

The survey was limited in its design and execution. Due to scheduling restrictions, the survey was released early in the Spring 2017 semester, and asked students about their experiences in the Fall 2016 semester. The amount of time that elapsed between the experience and survey may have introduced respondent bias. Additionally, the study can only reveal correlations between variables, not causation. In an ideal study, I would look at the motivation-stress relationship over time.

This study was also limited in its scope. I restricted my study to the population of BME undergraduates at UT Austin for convenience; I had the most connections with that department, and therefore ability to easily distribute my survey. The resulting participants may have been too homogenous in their perception of stress to reveal trends beyond the amotivation-stress relationship. However, the limited scope of this study is also a strength. It is important to understand the unique experiences of students in different domains. By focusing in on the UT BME undergraduate student population, I was able to reveal important trends in stress outcomes based on gender and academic classification. This specific information will allow me to develop motivation interventions attuned to the needs of the population.

In my future work, I will explore how we can aid students in developing skills to overcome academic challenges, support their sense of autonomy, and integrate them into the BME community. These interventions plans will focus specifically on male students and freshmen and sophomore students, as these were the critical populations revealed in my study. Such intervention plans will help shift students from amotivation to extrinsic motivation, thereby reducing stress.

Despite the importance of gaining information about unique populations, it is also valuable to learn about the motivation-stress relationship across all engineering. Scaling this study to all engineering majors across universities nationwide would reveal relationships representative of all engineering, instead of one engineering major at one school. Such information could then help inform national education policy.

Conclusion

This study supports the conclusion that amotivation is a positive predictor of stress. Students who experience greater amounts of amotivation toward their studies in biomedical engineering experience more stress. When students lack competence, control, and belonging to a subject matter, negative outcomes emerge. Without any sort of motivation for a particular subject, individuals may find it harder to commit to completing coursework, leaving them in academic situations that produce more stress, such a cramming last minute for a test or struggling over a homework set after skipping instructional time. It may also be that these students who lack motivation for BME fail to connect with peers in their cohort and their professors, resulting in a lack of social and academic support. It seems to be critical, therefore, to further explore the environmental factors that may moderate the amotivation-stress relationship. Using these and future results to develop intervention plans for specific populations will help to reduce stress levels in students, ultimately increasing student persistence in Biomedical Engineering at The University of Texas at Austin.

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Appendix A

Persistence

Continue in degree

Are you currently pursuing a B.S. in Biomedical Engineering at The University of Texas at Austin?

(1) Yes
(2) No

Do you plan to continue in BME next semester?

(3) Yes
(4) No

Confidence in completing degree

How likely are you to complete a B.S. in Biomedical Engineering?

Very Unlikely	Unlikely	Neither Likely nor Unlikely	Likely	Very Likely
1	2	3	4	5

Academic Motivation

For the following statements, please indicate how much you agree with the statements as they answer the guiding question:

Why are you studying Biomedical Engineering?

Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Disagree
1	2	3	4	5	6	7

1. In order to obtain a more prestigious job later on.
2. For the pleasure that I experience in broadening my knowledge about subjects that appeal to me.
3. Because eventually it will enable me to enter the job market in a field that I like.
4. For the pleasure that I experience when I read about advances in STEM.
5. Honestly, I don’t know; I feel that I am wasting my time in school.
6. For the pleasure that I experience while I am surpassing myself in one of my personal accomplishments.
7. Because I want to show myself that I can succeed.
8. Because I want to have “the good life” later on.
9. For the pleasure I experience when I discover new things never seen before.
10. Because this will help me make a better choice regarding my career orientation.

11. For the pleasure that I experience when I feel completely absorbed by what certain engineers have discovered.
12. I don't know; I can't understand what I am doing in school.
13. For the satisfaction I feel when I am in the process of accomplishing difficult academic activities.
14. Because of the fact that when I succeed in BME I feel important.
15. In order to have a better salary later on.
16. Because my studies allow me to continue to learn about many things that interest me.
17. Because I believe that a few additional years of education will improve my competence as a worker.
18. For the "high" feeling that I experience while reading about various BME subjects.
19. I can't see why I'm majoring in BME, and frankly, I couldn't care less.
20. Because BME allows me to experience a personal satisfaction in my quest for excellence in my studies.
21. To show myself that I am an intelligent person.

Perceived Stress

For each of the following statements, please indicate how often you have experienced each statement in the past month using the following scale:

0	Never
1	Almost Never
2	Sometimes
3	Fairly Often
4	Very Often

During the Fall 2016 semester, how often had you:
1. Been upset because of something that happened unexpectedly?
2. Felt that you were unable to control the important things in your life?
3. Felt nervous and "stressed"?
4. Felt confident about your ability to handle your personal problems?
5. Felt that things were going your way?
6. Could not cope with all the things you had to do?
7. Been able to control irritations in your life?
8. Felt that you were on top of things?
9. Been angered because of things that were outside of your control?
10. Felt difficulties were piling up so high that you could not overcome them?

Learning Climate

This section contains items that are related to your experience with the instructors in your classes this semester. Instructors have different styles in dealing with students, and we would like to know more about how you have felt about your encounters with your instructors this semester. Your responses are confidential. Please be honest and candid.

How have you felt about your encounters with your BME instructors this past semester?

Strongly Disagree	**Disagree**	**Somewhat Disagree**	**Neither Agree nor Disagree**	**Somewhat Agree**	**Agree**	**Strongly Disagree**
1	2	3	4	5	6	7

1. I feel that my instructors provide me choices and options.
2. I feel understood by my instructors.
3. My instructors conveyed confidence in my ability to do well in the course.
4. My instructors encouraged me to ask questions.
5. My instructors listen to how I would like to do things.
6. My instructors try to understand how I see things before suggesting a new way to do things.

Demographics

EID
What is your UT EID, starting with the last letter? (Ex. if your eid is sbg456, please report g456)
____

Age
How old are you? _____ years

Sex
What is your gender?
(1) Female
(2) Male
(3) Other

Race/ethnicity
What is your race/ethnicity? (please mark all that apply)
(1) African American or Black
(2) Asian, Pacific Islander, or Asian American
(3) European American or White
(4) Hispanic or Latino/a
(5) Native American
(6) Other, specify:____________

First-Generation Student
Are you the first in your family to go to university?
(1) Yes
(2) No

Year in school
What semester did you start at UT? (select one from each column)

Semester	Year
(1) Fall	(1) 2012
(2) Spring	(2) 2013
(3) Summer	(3) 2014
	(4) 2015
	(5) 2016

Year in Biomedical Engineering

What semester did you start your BME degree at UT? (select one from each column)

Semester	Year
(1) Fall	(1) 2012
(2) Spring	(2) 2013
(3) Summer	(3) 2014
	(4) 2015
	(5) 2016

GPA

What is your current overall GPA? _________

Hours

How many hours of coursework are you currently enrolled in? _________

Work

Do you have a paid job?

(1) Yes
(2) No

If yes, how many hours do you work in an average week?

(1) <10
(2) 10 – 14
(3) 15 – 19
(4) 20 – 29
(5) >30

What is the primary reason why you work?

(1) For financial reasons; I need the money
(2) To gain experiences for my future career
(3) For fun; I like my work
(4) Other, specify:____________

Funding College

How are you primarily paying for college?

(1) Scholarships
(2) Student loans
(3) Personal funds

(4) Parents/relatives

Environmental Information

Residence
Do you live on or off campus?
(1) On campus
(2) Off campus, within a 3-mile commute
(3) Off campus, beyond a 3-mile commute

First-Year Interest Group (FIG)
Are/were you a member of a First Year Interest Group (FIG)?
(1) Yes
(2) No

Student Organizations
Do you actively participate in any BME student organizations?
(1) Yes
(2) No

Career Development Activities
Have you participated in any of the following? (please mark all that apply)
(1) Undergraduate research at UT (ex. Undergraduate research assistant in Dr. Baker's Lab)
(2) Undergraduate research outside of UT (ex. REU at Georgia Tech)
(3) Internship (ex. Full-time summer employee at Stryker)
(4) Co-op (ex. Full-time employee at Genentech for six months)

Post-Graduation Plans
What are your anticipated post-graduate plans?
(1) Graduate school in STEM-related field (ex. MS or PhD)
(2) Graduate school in non-STEM-related field (ex. MS or PhD)
(3) Medical school (ex. MD, MPH, or other Health Professions degree)
(4) Industry (ex. Full-time employee at EPIC Technologies)
(5) Other, specify:____________

Table 1

Descriptive Statistics of Self-Reported Measures

Scale	No. of Items	M	SD	α	No. of Items	α
Modified AMS					AMS	
Amotivation	3	2.53	1.33	0.89	4	0.85
External Regulation	3	5.03	1.22	0.80	4	0.83
Introjected Regulation	3	5.11	1.23	0.81	4	0.84
Identified Regulation	3	5.41	0.94	0.57	4	0.62
Intrinsic Motivation to Know	3	5.64	0.91	0.81	4	0.84
Intrinsic Motivation to Accomplish	3	5.13	1.08	0.77	4	0.85
Intrinsic Motivation to Stimulate	3	4.75	1.23	0.80	4	0.86
Stress	10	2.09	0.60	0.84	-	-
Learning Climate	5	4.58	1.07	0.85	-	-

Note. N = 182 for all measures except learning climate, where N = 181. Modified AMS = 21-question Academic Motivation Scale used in this study, responses were recorded using a 7-point Likert scale ranging from 1 (Strongly Disagree) to 7 (Strongly Agree) and averaged. Averaged scores ranged from 1 – 7, with higher numbers correspond to greater levels of a certain motivation type; AMS = Academic Motivation Scale, alpha values reported from Vallerand et al. (1992); Stress was measured using the Perceived Stress Scale, ranging on a 5-point Likert scale from 0 (Never) to 4 (Very Often). Scores were averaged resulting in a range from 0 – 4, with higher scores indicate greater levels of perceived stress; Learning climate was measured using the 6-item Learning Climate Questionnaire (LCQ), scored on a 7-point Likert scale ranging from 1 (Strongly Disagree) to 7 (Strongly Agree). Scores were averaged, resulting in a range from 1 – 7, with higher numbers correspond to greater levels of perceived instructor autonomy support.

Table 2

Sample Demographics

Demographic Variable	Male		Female		Other		Total	
	N	%	N	%	N	%	N	%
Gender	71	39.01	109	59.89	2	1.10	182	100
Ethnicity								
African American	0	0	3	1.65	0	0	3	1.65
Asian, Pacific Islander, Asian American	23	12.64	45	24.73	0	0	68	37.36
European American or White	32	17.58	41	22.53	2	1.10	75	41.21
Hispanic or Latino/a	8	4.40	6	3.30	0	0	14	7.69
Native American	0	0	0	0	0	0	0	0
Other	1	0.55	3	1.65	0	0	4	2.2
More than two ethnicities selected	7	3.85	11	6.04	0	0	18	9.89
BME Start Semester								
Spring 2017	2	1.10	0	0	0	0	2	1.10
Fall 2016	12	6.59	25	13.74	0	0	37	20.33
Fall 2015	11	6.04	27	14.84	2	1.10	40	21.98
Spring 2015	1	0.55	0	0	0	0	1	0.55
Fall 2014	21	11.54	26	14.29	0	0	47	25.82
Fall 2013	23	12.64	29	15.93	0	0	52	28.57
Fall 2012	1	0.55	2	1.10	0	0	3	1.65

	Male		Female		Other		Total	
	M	SD	M	SD	M	SD	M	SD
Age	20.3	1.2	20.1	1.2	19	-	20.16	1.23

Note. Sample N = 182; BME = biomedical engineering.

Table 3

Stress and Motivation by Gender

Variable of Interest	Men		Women		Total			
	M	SD	M	SD	M	SD	W	p
Stress	1.99	0.66	2.17	0.55	2.10	0.60	3151	0.04*
RAI	20.6	6.27	21.74	5.64	21.27	5.88	3459	0.23
AUT	5.12	0.89	5.30	0.77	5.23	0.82	3436	0.20
CONT	4.97	0.93	5.11	0.98	5.06	0.99	3513	0.30
AMOT	2.49	1.42	2.55	1.29	2.52	1.34	3658	0.53
N	71		109		180			

Note. N = 180; Stress ranges from 0 – 4, with 4 being the greatest amount of perceived stress; RAI = relative autonomy index; AUT = autonomous motivation; CONT = controlled motivation; AMOT = amotivation; RAI ranges from -21 – 42, with 42 being the greatest amount of autonomous motivation; AUT, CONT, and AMOT all range from 0 – 7, with 7 being the greatest amount of a particular type of motivation; Wilcoxon rank-sum test performed for all variables; * - significant for alpha = 0.05.

Table 4

Stress and Motivation by Time in Degree

Semester Start BME	Spring 2017		Fall 2016		Fall 2015		Spring 2015		Fall 2014		Fall 2013		Fall 2012			
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	χ^2	p
Stress	2.25	0.49	2.00	0.67	2.13	0.58	2.80	-	2.16	0.63	2.10	0.55	1.43	0.21	7.16	0.30
RAI	24.83	6.84	22.03	5.43	21.21	5.65	25.00	-	22.06	6.24	20.08	6.20	18.78	3.34	5.25	0.51
AUT	6.00	0.94	5.42	0.75	5.33	0.86	5.58	-	5.21	0.82	5.00	0.83	5.25	0.46	8.72	0.19
CONT	5.58	0.12	5.21	0.96	5.35	1.09	5.67	-	4.83	0.88	4.87	0.90	5.83	0.17	15.43	0.02*
AMOT	1.67	0.94	2.49	1.34	2.42	1.30	3.67	-	2.43	1.32	2.70	1.43	3.00	0.88	4.32	0.63
N	2		37		38		1		47		52		3			

Academic Classification	Underclassmen			Upperclassmen				
	M	SD	N	M	SD	N	W	p
Stress	2.08	0.62	78	2.11	0.59	102	3893	0.81
RAI	21.68	5.45	78	20.95	6.20	102	4245	0.64
AUT	5.39	0.82	78	5.10	0.82	102	4870.5	0.01*
CONT	5.29	1.00	78	4.88	0.89	102	5096	<0.01*
AMOT	2.45	1.31	78	2.58	1.36	102	3781	0.57

Note. N = 182; RAI = relative autonomy index; AUT = autonomous motivation; CONT = controlled motivation; AMOT = amotivation; Underclassmen = Spring 2017, Fall 2016, Fall 2015, and Spring 2015; Upperclassmen = Fall 2014, Fall 2013, and Fall 2012; Kruskal-Wallis test for stress, all motivation variables by Semester Start BME; Wilcoxon rank-sum test for stress and all motivation variables by Academic Classification; * - significant for alpha = 0.05.

Table 5

Stress and Motivation by Post-Graduation Plans

Post-Graduation Plans	Grad School, STEM		Grad School, non-STEM		Med School		Industry		Other			
	M	SD	M	SD	M	SD	M	SD	M	SD	χ^2	p
Stress	2.09	0.58	2.29	0.72	2.01	0.55	2.16	0.63	1.88	0.68	2.37	0.67
RAI	23.72	5.55	18.13	8.08	21.13	5.83	20.05	5.52	23.50	4.94	16.01	<0.01*
AUT	5.46	0.77	4.47	0.94	5.20	0.81	5.16	0.79	5.60	0.99	12.26	0.02*
CONT	4.83	1.02	4.50	0.86	5.08	1.01	5.24	0.83	5.38	1.27	8.47	0.08
AMOT	2.04	1.21	4.00	2.00	2.39	1.19	2.77	1.30	2.58	1.20	16.23	<0.01*
N	46		8		52		70		5			

Post-Graduation Classification	Corporate			Further Education				
	M	SD	N	M	SD	N	W	p
Stress	2.14	0.63	74	2.07	0.58	106	4196	0.43
RAI	20.23	5.52	74	22.03	6.08	106	3165	0.03*
AUT	5.19	0.80	74	5.26	0.84	106	3627	0.39
CONT	5.24	0.85	74	4.93	1.01	106	4609	0.05*
AMOT	2.76	1.29	74	2.36	1.35	106	4773	0.01*

Note. N = 180; STEM = science, technology, engineering, and math; RAI = relative autonomy index; AUT = autonomous motivation; CONT = controlled motivation; AMOT = amotivation; Corporate = Industry, Other; Further Education = Grad School, STEM; Grad School, non-STEM; and Med School; Kruskal-Wallis test for stress, all motivation variables by Post-Graduation Plans; Wilcoxon rank-sum test for stress and all motivation variables by Post-Graduation Classification; * - significant for alpha = 0.05.

Table 6

Predictors for Perceived Stress

Correlation Coefficient (p)	Stress	RAI	AUT	CONT	AMOT
Stress	-	-	-	-	-
RAI	-0.07 (0.36)	-	-	-	-
AUT	-0.08 (0.31)	0.82 (<0.01)*	-	-	-
CONT	0.00 (0.97)	-0.09 (0.23)	0.42 (<0.01)*	-	-
AMOT	0.20 (0.01)*	-0.47 (<0.01)*	-0.48 (<0.01)*	-0.04 0.61)	-
Start BME	0.00 (0.96)	-0.10 (0.19)	-0.21 (<0.01)*	-0.18 (0.02)*	0.08 (0.29)

Note. Spearman's correlation coefficient was calculated for non-normal variables; RAI = relative autonomy index; AUT = autonomous motivation; CONT = controlled motivation; AMOT = amotivation; BME = biomedical engineering; EXT = extrinsic motivation; INT = intrinsic motivation; Start BME = the semester a student started his/her BME coursework; * - significant for alpha = 0.05.

Table 7

Linear Regression Models for Perceived Stress with Amotivation

Model	B	SE	t	p	R^2
Model 1 – AMOT			13.95	<0.01*	0.07
Intercept	1.79	0.09	19.33	<0.01*	
AMOT	0.12	0.03	3.74	<0.01*	
Model 2 – AMOT + Gender			7.68	<0.01*	0.10
Intercept	1.50	0.14	10.92	<0.01*	
AMOT	0.20	0.05	4.08	<0.01*	
Gender	0.52	0.18	2.82	0.01*	
AMOT x Gender	-0.14	0.06	-2.11	0.04*	
Model 3 – AMOT + AC			5.592	<0.01*	0.07
Intercept	1.63	0.14	11.61	<0.01*	
AMOT	0.19	0.05	3.68	<0.01*	
AC	0.28	0.19	1.52	0.13	
AMOT x AC	-0.11	0.07	-1.66	0.10	
Model 4 – AMOT + PGC			4.91	<0.01*	0.06
Intercept	1.71	0.16	10.61	<0.01*	
AMOT	0.16	0.05	2.94	<0.01*	
PGC	0.12	0.20	0.63	0.53	
AMOT x PGC	-0.06	0.07	-0.87	0.39	
Model 5 – AMOT + G + AC + PGC			4.10	<0.01*	0.11
Intercept	1.17	0.23	5.18	<0.01*	
AMOT	0.32	0.08	4.23	<0.01*	
G	0.58	0.19	3.04	<0.01*	
AMOT x G	-0.16	0.07	-2.30	0.02*	
AC	0.40	0.19	2.12	0.04*	
AMOT x AC	-0.15	0.07	-2.21	0.03*	
PGC	0.11	0.20	0.55	0.59	
AMOT x PGC	-0.05	0.07	-0.67	0.51	

Note. AMOT = amotivation; AC = academic classification (underclassman or upperclassman); PGC = post-graduation classification (corporate or further education); G = gender.

Table 8

Linear Regression Models for Perceived Stress with Amotivation - Centered

Model	B	SE	t	p	R^2
Model 6 – AMOT			13.95	<0.01*	0.07
Intercept	0	<0.01	0	1	
AMOT	0.12	0.03	3.74	<0.01*	
Model 7 – AMOT + Gender			7.68	<0.01*	0.10
Intercept	0	0.04	0.04	0.97	
AMOT	0.11	0.03	3.54	<0.01*	
Gender	0.18	0.09	2.02	0.05*	
AMOT x Gender	-0.14	0.06	-2.11	0.04*	
Model 8 – AMOT + AC			5.592	<0.01*	0.07
Intercept	0.00	0.04	0.08	0.94	
AMOT	0.12	0.03	3.80	<0.01*	
AC	0.01	0.09	0.09	0.93	
AMOT x AC	-0.11	0.07	-1.66	0.10	
Model 9 – AMOT + PGC			4.91	<0.01*	0.06
Intercept	-0.01	0.04	-0.13	0.90	
AMOT	0.12	0.03	3.68	<0.01*	
PGC	-0.02	0.09	-0.27	0.79	
AMOT x PGC	-0.06	0.07	-0.87	0.39	
Model 10 – AMOT + G + AC + PGC			4.10	<0.01*	0.11
Intercept	0.00	0.04	0.05	0.96	
AMOT	0.12	0.03	3.58	<0.01*	
G	0.18	0.09	2.09	0.04*	
AMOT x G	-0.16	0.07	-2.30	0.02*	
AC	-0.03	0.09	0.31	0.76	
AMOT x AC	-0.15	0.07	-2.21	0.03*	
PGC	-0.01	0.09	-0.09	0.93	
AMOT x PGC	-0.05	0.07	-0.67	0.51	

Note. AMOT = amotivation; AC = academic classification (underclassman or upperclassman); PGC = post-graduation classification (corporate or further education); G = gender.

Table 9

Probing Gender Interactions in Model 10

Model	B	SE	t	p	R^2
Model 11 – Men			4.10	<0.01*	0.11
Intercept	-0.11	0.07	-1.58	0.12	
AMOT	0.21	0.05	4.20	<0.01*	
G	0.18	0.09	2.09	0.04*	
AMOT x G	-0.16	0.07	-2.30	0.02*	
AC	-0.03	0.09	0.31	0.76	
AMOT x AC	-0.15	0.07	-2.21	0.03*	
PGC	-0.01	0.09	-0.09	0.93	
AMOT x PGC	-0.05	0.07	-0.67	0.51	
Model 12 – Women			4.10	<0.01*	0.11
Intercept	0.07	0.05	1.36	0.17	
AMOT	0.05	0.04	1.24	0.22	
G	-0.18	0.09	-2.09	0.04*	
AMOT x G	0.16	0.07	2.30	0.03*	
AC	0.03	0.09	0.31	0.76	
AMOT x AC	-0.15	0.07	-2.21	0.02*	
PGC	-0.01	0.09	-0.09	0.93	
AMOT x PGC	-0.05	0.07	-0.67	0.51	

Note. AMOT = amotivation; AC = academic classification (underclassman or upperclassman); PGC = post-graduation classification (corporate or further education); G = gender, not centered. For Model 11, men are coded as “0”; for Model 12, women are coded as “0”.

Table 10

Probing Academic Classification Interactions in Model 10

Model	B	SE	t	p	R^2
Model 13 – upperclassmen			4.10	<0.01*	0.11
Intercept	0.01	0.06	0.24	0.81	
AMOT	0.05	0.04	1.22	0.22	
G	0.18	0.09	2.09	0.04*	
AMOT x G	-0.16	0.07	-2.30	0.02*	
AC	-0.03	0.09	-0.31	0.76	
AMOT x AC	0.15	0.07	2.21	0.03*	
PGC	-0.01	0.09	-0.09	0.93	
AMOT x PGC	-0.05	0.07	-0.67	0.51	
Model 14 – underclassmen			4.10	<0.01*	0.11
Intercept	-0.01	0.07	-0.20	0.84	
AMOT	0.20	0.05	3.95	<0.01*	
G	0.18	0.09	2.09	0.04*	
AMOT x G	-0.16	0.07	-2.30	0.02*	
AC	0.03	0.09	0.31	0.76	
AMOT x AC	-0.15	0.07	-2.21	0.03*	
PGC	-0.01	0.09	-0.09	0.93	
AMOT x PGC	-0.05	0.07	-0.67	0.51	

Note. AMOT = amotivation; AC = academic classification (underclassman or upperclassman), not centered; PGC = post-graduation classification (corporate or further education); G = gender. For Model 13, upperclassmen are coded as “0”; for Model 14, underclassmen are coded as “0”.

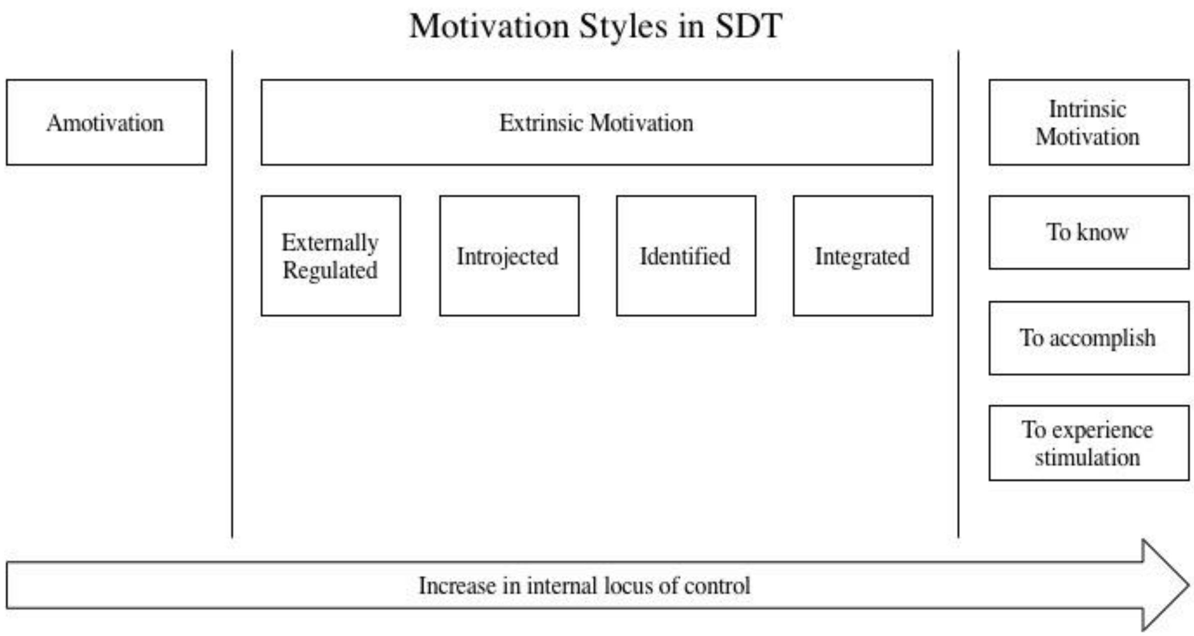

Figure 1. The spectrum of motivational styles as described by the Self-Determination Theory, ranging from least autonomous on the left, excluding amotivation, to most autonomous on the right.

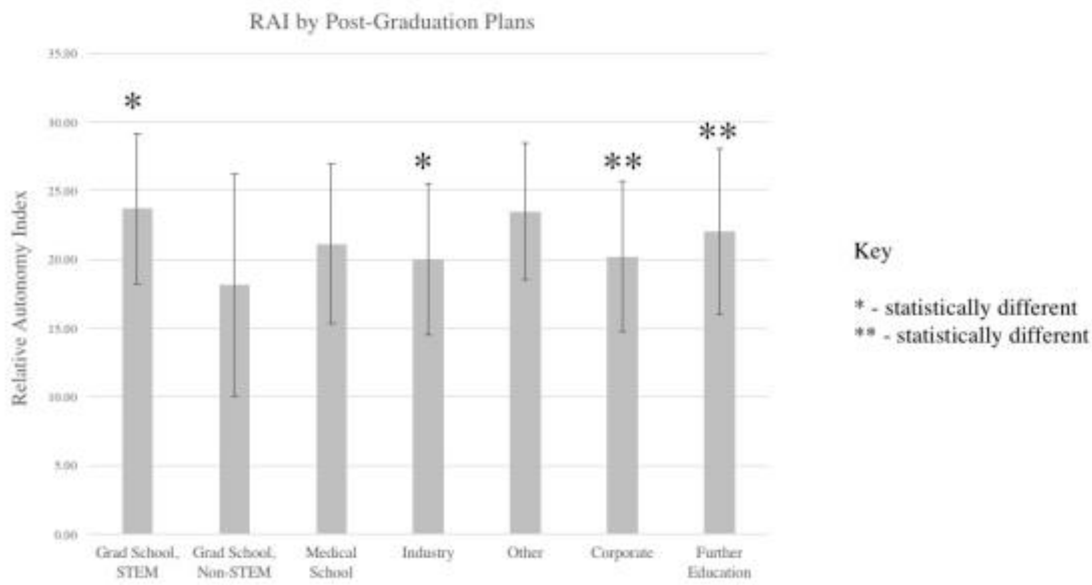

Figure 2. Relative Autonomy Index (RAI) by post-graduation plans (five groups) and post-graduation classification (corporate = industry, other; further education = grad school, STEM and non-STEM, and medical school). There was a significant difference in RAI between students intending to pursue STEM-related graduate school (mean = 23.67, SD = 5.51) versus students intending to go into industry (mean = 20.02, SD = 5.50) ($p < 0.01$). There was also a significant difference in RAI between the corporate and further education groups (mean = 20.20, SD = 5.49; mean = 22.02, SD = 6.05; $p = 0.02$).

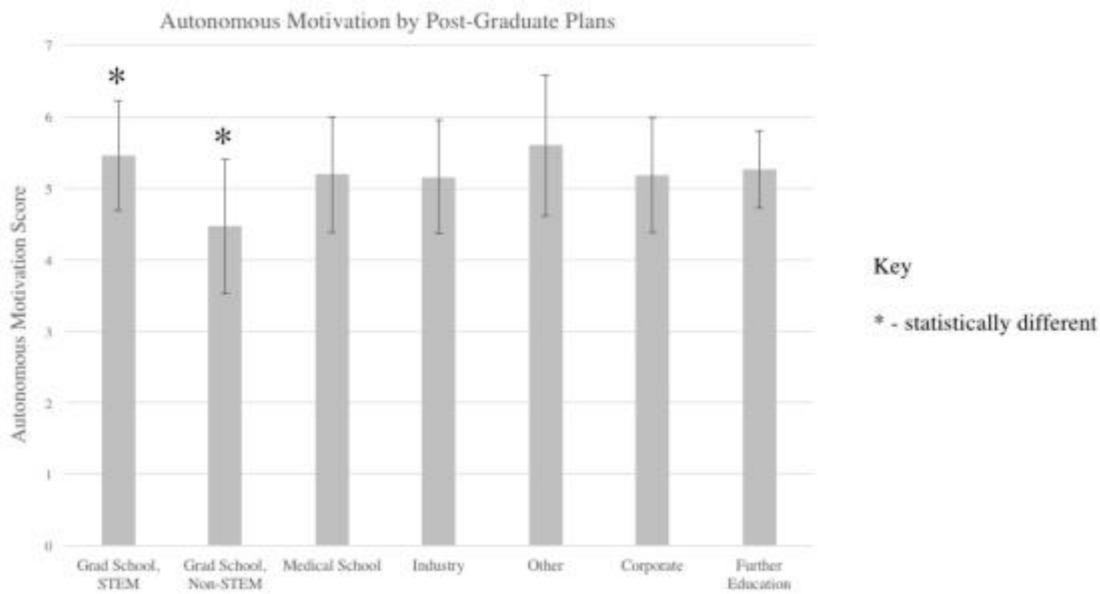

Figure 3. Autonomous motivation by post-graduation plans (five groups) and post-graduation classification (corporate = industry, other; further education = grad school, STEM and non-STEM, and medical school). There was a significant difference in autonomous motivation between students intending to pursue STEM-related graduate school (mean = 5.46, SD = 0.77) versus students intending to pursue non-STEM-related graduate school (mean = 4.47, SD = 0.94) ($p = 0.03$).

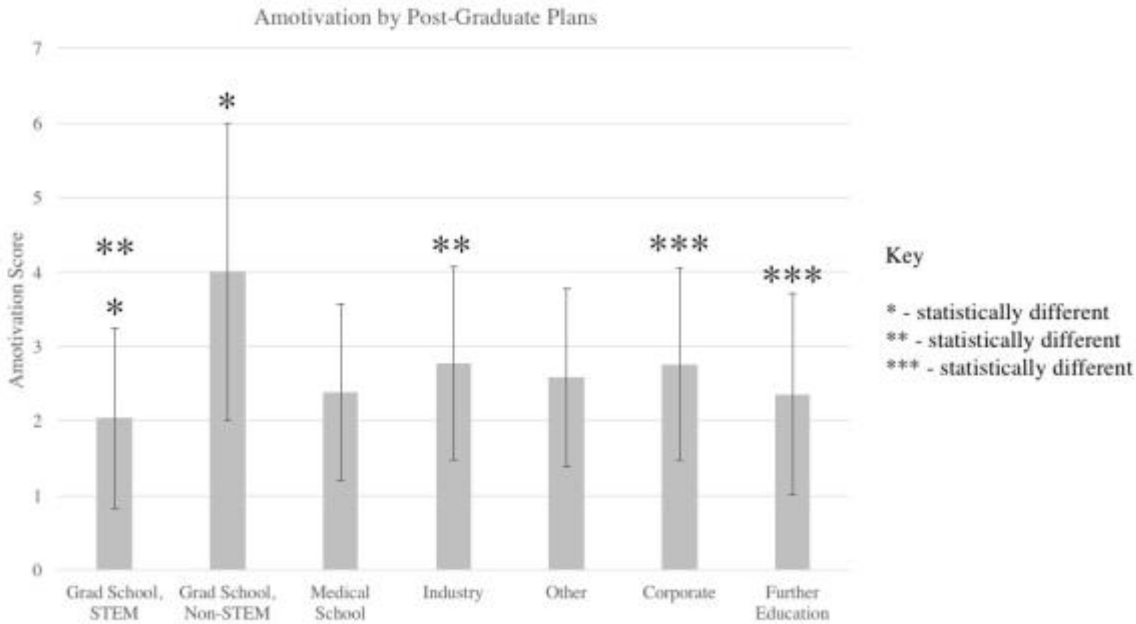

Figure 4. Amotivation by post-graduation plans (five groups) and post-graduation classification (corporate = industry, other; further education = grad school, STEM and non-STEM, and medical school). There was a significant difference in amotivation between students intending to pursue STEM-related graduate school (mean = 2.04, SD = 1.21) versus students intending to pursue non-STEM-related grad school (mean = 4.00, SD = 2.00, p = 0.02) or students intending to go into industry (mean = 2.77, SD = 1.30, p = 0.01). There was also a significant difference in amotivation between the corporate and further education groups (mean = 2.76, SD = 1.29; mean = 2.36, SD = 1.35; p = 0.01).

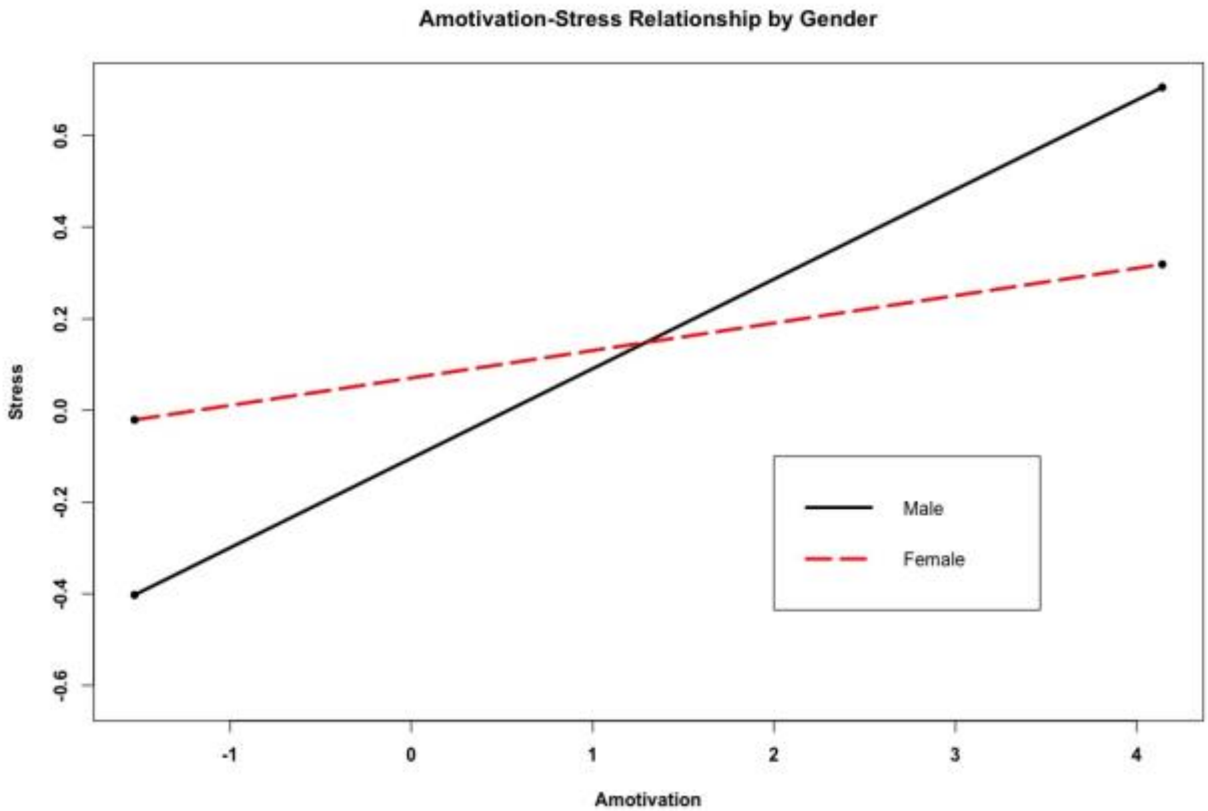

Figure 5. Visualization of the linear regression between amotivation and perceived stress by gender, using centered values for amotivation and stress. Other variables were omitted for the purposes of visualization. As shown in the graph, the positive trend between amotivation and stress is greater for males than for females.

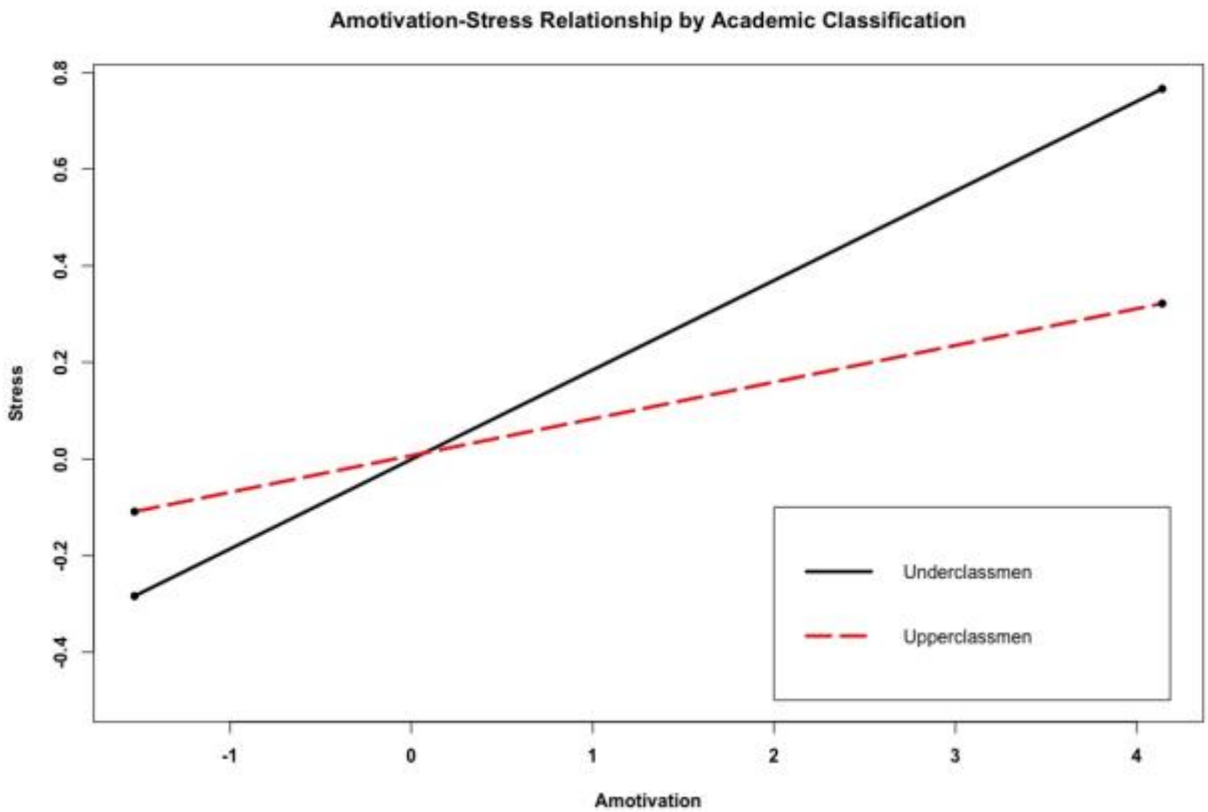

Figure 6. Visualization of the linear regression between amotivation and perceived stress by academic classification, using centered values for amotivation and stress. Other variables were omitted for the purposes of visualization. As shown in the graph, the positive trend between amotivation and stress is greater for underclassmen than for upperclassmen.

Biography

Amanda Meriwether is a fourth year Biomedical Engineering and Plan II Honors student at The University of Texas at Austin, concurrently pursuing a Master's Certificate in Public Health at The University of Texas Health Science Center at Houston. She hopes to continue her research in engineering education through coursework while pursuing a PhD in Biomedical Engineering. Using her technical knowledge in biomedical engineering and engineering education, Amanda hopes to one day transform the engineering learning environment through informed teaching practices.